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TECHNICAL MEMORANDUM No. 4/M/54

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Tables for the Calculation of Combustion Temperatures and Specific Impulses of Propellants

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Tables for the Calculation of Combustion Temperatures and Specific Impulses of Propellants

by

J.H.C. Vernon

This memorandum does not contain classified information of overseas origin.

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CONTENTS

Reference: XR 410/40

1. SUMMARY

A number of tables and a nomograph for calculating the combustion temperature and specific impulse of propellants are presented. The tables are extensions and modification of those already given by Pike. It is claimed that their use, in conjunction with the nomograph, considerably reduces the labour of calculating specific impulse.

2. INTRODUCTION

2.1 Combustion temperature and specific impulse of propellants are normally calculated by the method described by Pike (A.R.E. Report No. 25/49), with the aid of thermochemical data presented in the form of tables in his report. These calculations are rather laborious, each taking two or three hours, even when only approximate answers are required (e.g., as obtained by disregarding the effect of thermal dissociation on the products of combustion). More rapid and convenient computation of propellant performance can be achieved, however, if certain extensions are made to the tables, and if a nomograph is used for the final calculation of S.I. from combustion temperature and the number of moles of combustion products.

Such extended tables, and the nomograph, are presented here. The layout of the tables is similar to that used by Pike. The tables differ from Pike's in the following respects:

(i) Specific Heats

In computations on propellants, the specific heat at constant pressure is used, rather than that at constant volume. Pike's table for the Cv of the resultant gases has therefore been replaced by one giving Cp directly.

In Pike's table, data are given at 100° intervals, and the interpolation of intermediate values is not always linear. Over the range 1000° - 3700°K., therefore, the data have been accurately interpolated to 20° intervals. Over more than 95% of the table a linear interpolation to 10° intervals may legitimately be made.

Owing to the interest in propellants containing ammonium perchlorate, data for the combustion product HCl have been added.

Data for graphite, for which the term C_p can have no meaning, have been omitted.

(ii) Equilibrium Constants

These have similarly been recalculated to 20° intervals. The data are expressed in the form of natural numbers, the form used in computation, and not, as in Pike's table, as logarithms. For convenience of layout, the constants have been divided into two groups.

2.2 Specific Impulse

There are several equivalent equations for specific impulse, the following forms of the equation is best adapted to tabulation:

$$SI_{1000} = 0.4158 \, (N \, T_c)^{\frac{1}{2}} \, G'$$

/where:

where: N = total number of moles of resultant gases per 100 kg.,

T_c = calculated combustion temperature

$$G' = \left\{\frac{\gamma}{\gamma - 1}\left\{1 - \frac{(14.7)}{(1000)}\frac{\gamma - 1}{\gamma}\right\}\right\}^{\frac{1}{2}}$$

$\gamma = C_p/C_v$ = the ratio of the specific heat/mole at constant pressure to that at constant volume, for the resultant gases.

The use of this equation, however, is very laborious, particularly the calculation of G; an additional table (Table 3) is therefore presented, giving values of G' for all values of C_p likely to be met with in practice. The specific impulse may then be calculated by means of the above equation, or using the nomogram, which performs the same calculation.

2.3 Newer Values of Specific Heats

After the tables in this Memorandum had been calculated, it was pointed out by Dr. Pike in a letter, that the specific heats of hydrogen and carbon monoxide have recently been redetermined in the United States. As the small differences between these data and Pike's would have a negligible effect on the calculated specific impulse, it was decided not to recalculate these columns of the table.

/Table 1

TABLE 1

Mean Specific Heats at Constant Pressure, Cp, between 300° and T°K.

In cal./mole. °K.

T°K.	CO_2	H_2O	CO	H_2	N_2	O_2	OH	NO	HCl	CH_4	NH_3
300	7.514	7.937	6.951	6.788	6.950	6.942	7.064	7.364		8.039	8.067
300	8.891	8.029	6.965	6.895	6.961	7.019	7.140	7.145	6.985	8.573	8.508
400	9.399	8.102	6.983	6.945	6.973	7.097	7.199	7.146	6.999	9.121	8.830
500	9.840	8.199	7.022	6.965	7.000	7.207	7.078	7.182	7.014	9.786	9.195
600	10.225	8.315	7.080	6.974	7.043	7.321	7.068	7.252	7.039	10.484	9.568
700	10.563	8.439	7.151	6.987	7.100	7.435	7.067	7.333	7.065	11.179	9.938
800	10.863	8.573	7.228	7.002	7.167	7.543	7.077	7.416	7.094	11.853	10.302
900	11.132	8.712	7.308	7.020	7.238	7.643	7.095	7.500	7.134	12.497	10.658
1000	11.372	8.855	7.387	7.042	7.310	7.734	7.118	7.581	7.181	13.109	11.003
1020	11.418	8.884	7.403	7.047	7.325	7.751	7.123	7.597	7.191	13.228	11.072
1040	11.462	8.913	7.419	7.052	7.340	7.768	7.128	7.613	7.201	13.345	11.139
1060	11.505	8.942	7.434	7.058	7.354	7.784	7.134	7.628	7.211	13.461	11.206
1080	11.547	8.971	7.449	7.063	7.368	7.800	7.140	7.643	7.221	13.575	11.272
1100	11.588	9.000	7.464	7.069	7.382	7.816	7.147	7.657	7.231	13.687	11.336
1120	11.629	9.030	7.479	7.075	7.396	7.832	7.154	7.672	7.241	13.799	11.401
1140	11.669	9.059	7.494	7.081	7.410	7.847	7.161	7.686	7.251	13.909	11.465
1160	11.708	9.088	7.508	7.087	7.424	7.862	7.168	7.700	7.261	14.018	11.529
1180	11.746	9.117	7.522	7.094	7.438	7.876	7.175	7.714	7.271	14.125	11.593
1200	11.783	9.146	7.536	7.101	7.452	7.890	7.183	7.728	7.281	14.230	11.656
1220	11.820	9.175	7.550	7.108	7.466	7.904	7.191	7.742	7.291	14.334	11.719
1240	11.856	9.204	7.564	7.115	7.480	7.918	7.200	7.755	7.301	14.437	11.781
1260	11.891	9.233	7.578	7.122	7.493	7.932	7.209	7.768	7.311	14.550	11.842
1280	11.925	9.262	7.591	7.130	7.506	7.945	7.218	7.781	7.321	14.660	11.902
1300	11.959	9.291	7.604	7.137	7.519	7.958	7.227	7.794	7.331	14.739	11.962
1320	11.992	9.320	7.617	7.144	7.532	7.971	7.236	7.807	7.341	14.837	12.021
1340	12.025	9.349	7.630	7.151	7.545	7.984	7.245	7.819	7.351	14.934	12.080
1360	12.057	9.378	7.643	7.159	7.558	7.996	7.255	7.831	7.361	15.029	12.139
1380	12.088	9.407	7.656	7.167	7.570	8.008	7.265	7.843	7.371	15.122	12.197
1400	12.119	9.435	7.668	7.175	7.582	8.020	7.275	7.855	7.381	15.215	12.255
1420	12.150	9.463	7.680	7.183	7.594	8.032	7.285	7.867	7.391	15.307	12.312
1440	12.180	9.492	7.692	7.191	7.606	8.044	7.294	7.879	7.401	15.397	12.368
1460	12.209	9.520	7.704	7.199	7.618	8.056	7.304	7.890	7.411	15.486	12.424
1480	12.237	9.548	7.716	7.207	7.630	8.067	7.314	7.901	7.421	15.574	12.479
1500	12.265	9.576	7.728	7.215	7.641	8.078	7.323	7.912	7.431	15.659	12.533
1520	12.292	9.604	7.740	7.223	7.653	8.089	7.332	7.923	7.441	15.745	12.587
1540	12.319	9.632	7.751	7.232	7.664	8.100	7.342	7.934	7.451	15.830	12.640
1560	12.346	9.659	7.762	7.240	7.675	8.111	7.351	7.944	7.461	15.914	12.693
1580	12.372	9.686	7.773	7.249	7.686	8.121	7.361	7.954	7.471	15.996	12.746
1600	12.398	9.713	7.784	7.257	7.697	8.131	7.370	7.964	7.481	16.076	12.798
1620	12.423	9.740	7.795	7.265	7.708	8.141	7.379	7.974	7.491	16.156	12.850
1640	12.448	9.767	7.806	7.274	7.719	8.151	7.389	7.984	7.501	16.235	12.901
1660	12.472	9.794	7.816	7.282	7.729	8.161	7.398	7.994	7.511	16.313	12.951
1680	12.496	9.821	7.826	7.291	7.740	8.171	7.408	8.003	7.521	16.389	13.000
1700	12.520	9.847	7.836	7.300	7.750	8.181	7.417	8.012	7.530	16.464	13.049

Table 1 (Cont.)

TABLE 1 (Cont.)

Mean Specific Heats at Constant Pressure, Cp, between 300° and T°K.

In cal./mole. °K.

T°K	CO_2	H_2O	CO	H_2	N_2	O_2	OH	NO	HCl	CH_4	NH_3
1720	12.543	9.873	7.846	7.309	7.760	8.191	7.426	8.021	7.540	16.538	13.098
1740	12.566	9.899	7.856	7.317	7.770	8.201	7.435	8.030	7.550	16.612	13.146
1760	12.588	9.925	7.866	7.326	7.780	8.210	7.444	8.039	7.560	16.685	13.193
1780	12.610	9.951	7.875	7.335	7.790	8.219	7.453	8.047	7.570	16.757	13.240
1800	12.632	9.976	7.884	7.344	7.800	8.228	7.462	8.055	7.580	16.827	13.286
1820	12.654	10.002	7.894	7.353	7.810	8.237	7.471	8.063	7.589	16.896	13.332
1840	12.675	10.028	7.903	7.361	7.820	8.246	7.480	8.071	7.598	16.964	13.377
1860	12.696	10.053	7.912	7.370	7.829	8.255	7.488	8.079	7.607	17.032	13.422
1880	12.716	10.078	7.921	7.379	7.838	8.264	7.497	8.087	7.616	17.100	13.467
1900	12.735	10.102	7.929	7.388	7.847	8.273	7.506	8.095	7.625	17.167	13.511
1920	12.755	10.127	7.938	7.397	7.856	8.281	7.515	8.103	7.634	17.233	13.555
1940	12.775	10.151	7.947	7.406	7.865	8.290	7.523	8.111	7.642	17.298	13.598
1960	12.794	10.175	7.955	7.414	7.874	8.298	7.532	8.118	7.651	17.361	13.641
1980	12.813	10.199	7.963	7.423	7.882	8.307	7.540	8.125	7.660	17.423	13.683
2000	12.831	10.223	7.971	7.432	7.890	8.315	7.549	8.133	7.668	17.484	13.724
2020	12.850	10.247	7.980	7.441	7.898	8.323	7.557	8.140	7.677		
2040	12.868	10.270	7.988	7.449	7.906	8.332	7.566	8.148	7.685		
2060	12.886	10.293	7.996	7.458	7.914	8.340	7.574	8.155	7.694		
2080	12.903	10.316	8.004	7.467	7.922	8.348	7.583	8.162	7.702		
2100	12.920	10.339	8.011	7.476	7.930	8.356	7.591	8.169	7.711		
2120	12.937	10.362	8.019	7.485	7.938	8.364	7.599	8.176	7.719		
2140	12.954	10.385	8.027	7.493	7.946	8.372	7.608	8.183	7.728		
2160	12.970	10.407	8.034	7.502	7.954	8.380	7.616	8.189	7.736		
2180	12.986	10.429	8.041	7.510	7.961	8.388	7.624	8.196	7.744		
2200	13.002	10.451	8.048	7.519	7.968	8.396	7.632	8.203	7.752		
2220	13.018	10.473	8.055	7.527	7.976	8.404	7.640	8.210	7.760		
2240	13.034	10.495	8.062	7.536	7.983	8.411	7.649	8.216	7.767		
2260	13.049	10.516	8.069	7.544	7.990	8.419	7.657	8.223	7.775		
2280	13.064	10.537	8.076	7.553	7.997	8.426	7.665	8.229	7.782		
2300	13.079	10.559	8.083	7.561	8.004	8.434	7.673	8.235	7.790		
2320	13.094	10.580	8.090	7.569	8.011	8.442	7.681	8.241	7.797		
2340	13.109	10.600	8.096	7.578	8.018	8.449	7.690	8.247	7.805		
2360	13.123	10.621	8.103	7.586	8.025	8.457	7.698	8.253	7.812		
2380	13.137	10.641	8.109	7.592	8.032	8.464	7.706	8.259	7.819		
2400	13.151	10.661	8.115	7.602	8.038	8.471	7.714	8.265	7.826		
2420	13.165	10.681	8.121	7.610	8.045	8.478	7.722	8.271	7.833		
2440	13.179	10.701	8.128	7.619	8.052	8.484	7.730	8.276	7.840		
2460	13.192	10.721	8.134	7.627	8.058	8.491	7.738	8.282	7.847		
2480	13.205	10.740	8.140	7.635	8.064	8.497	7.746	8.287	7.854		
2500	13.218	10.760	8.146	7.643	8.070	8.503	7.754	8.293	7.861	18.806	14.631
2520	13.231	10.779	8.152	7.651	8.077	8.511	7.762	8 298	7.868		
2540	13.244	10.798	8.158	7.659	8.083	8.519	7.771	8.304	7.875		
2560	13.257	10.817	8.164	7.667	8.089	8.526	7.779	8.309	7.882		
2580	13.270	10.836	8.170	7.675	8.095	8.534	7.788	8.314	7.889		
2600	13.282	10.855	8.176	7.683	8.101	8.542	7.796	8.319	7.896		

/Table 1 (Cont.)

TABLE 1 (Cont.)

Mean Specific Heats at Constant Pressure, Cp, between 300° and T°K.

In cal./mole. °K.

T°K.	CO_2	H_2O	CO	H_2	N_2	O_2	OH	NO	HCl	CH_4	NH_3
2620	13.294	10.873	8.182	7.691	8.107	8.549	7.802	8.324	7.903		
2640	13.306	10.892	8.188	7.699	8.113	8.555	7.809	8.329	7.910		
2660	13.318	10.910	8.193	7.706	8.119	8.562	7.817	8.334	7.916		
2680	13.330	10.938	8.199	7.714	8.125	8.568	7.825	8.339	7.922		
2700	13.342	10.946	8.204	7.722	8.130	8.576	7.833	8.344	7.928		
2720	13.354	10.964	8.210	7.730	8.136	8.583	7.841	8.349	7.934		
2740	13.365	10.981	8.215	7.737	8.142	8.589	7.848	8.354	7.938		
2760	13.376	10.999	8.220	7.745	8.147	8.596	7.856	8.359	7.944		
2780	13.388	11.016	8.225	7.753	8.153	8.602	7.863	8.364	7.949		
2800	13.398	11.033	8.230	7.760	8.158	8.609	7.871	8.369	7.954		
2820	13.409	11.050	8.235	7.767	8.164	8.615	7.878	8.374	7.959		
2840	13.420	11.067	8.240	7.775	8.169	8.622	7.886	8.378	7.964		
2860	13.431	11.084	8.245	7.782	8.174	8.628	7.893	8.383	7.969		
2880	13.441	11.100	8.249	7.790	8.179	8.635	7.900	8.387	7.974		
2900	13.451	11.117	8.254	7.797	8.184	8.641	7.907	8.391	7.979		
2920	13.461	11.133	8.259	7.804	8.189	8.647	7.914	8.395	7.983		
2940	13.471	11.149	8.264	7.812	8.194	8.654	7.921	8.400	7.987		
2960	13.481	11.165	8.268	7.819	8.199	8.660	7.928	8.404	7.991		
2980	13.491	11.181	8.273	7.826	8.204	8.666	7.935	8.408	7.995		
3000	13.501	11.197	8.277	7.833	8.208	8.672	7.942	8.412	7.999	19.794	15.330
3020	13.511	11.213	8.282	7.840	8.213	8.678	7.949	8.416	8.004		
3040	13.521	11.229	8.286	7.847	8.218	8.685	7.955	8.420	8.009		
3060	13.531	11.244	8.290	7.854	8.223	8.691	7.962	8.424	8.013		
3080	13.540	11.260	8.295	7.861	8.227	8.697	7.968	8.428	8.017		
3100	13.549	11.275	8.299	7.868	8.232	8.703	7.975	8.432	8.021		
3120	13.559	11.290	8.304	7.875	8.237	8.709	7.982	8.436	8.025		
3140	13.568	11.305	8.308	7.882	8.241	8.715	7.988	8.440	8.029		
3160	13.577	11.320	8.312	7.888	8.246	8.721	7.995	8.444	8.033		
3180	13.586	11.334	8.317	7.895	8.250	8.727	8.002	8.448	8.037		
3200	13.595	11.349	8.321	7.902	8.255	8.733	8.008	8.452	8.040		
3220	13.604	11.364	8.325	7.909	8.260	8.739	8.015	8.456	8.043		
3240	13.613	11.378	8.330	7.915	8.264	8.745	8.021	8.460	8.046		
3260	13.622	11.392	8.334	7.922	8.269	8.751	8.028	8.463	8.049		
3280	13.630	11.407	8.338	7.929	8.273	8.757	8.034	8.467	8.052		
3300	13.638	11.421	8.342	7.935	8.377	8.763	8.040	8.471	8.055		
3320	13.647	11.435	8.346	7.941	8.281	8.769	8.046	8.475	8.058		
3340	13.655	11.449	8.351	7.948	8.285	8.775	8.052	8.479	8.061		
3360	13.664	11.463	8.355	7.954	8.289	8.780	8.058	8.482	8.064		
3380	13.672	11.476	8.359	7.961	8.293	8.786	8.064	8.486	8.067		
3400	13.680	11.490	8.363	7.968	8.297	8.792	8.070	8.490	8.070		
3420	13.688	11.503	8.366	7.975	8.301	8.798	8.076	8.494	8.073		
3440	13.696	11.517	8.370	7.981	8.305	8.803	8.082	8.497	8.076		
3460	13.704	11.530	8.373	7.988	8.309	8.809	8.087	8.501	8.079		
3480	13.712	11.543	8.376	7.994	8.312	8.814	8.093	8.504	8.082		
3500	13.720	11.556	8.379	8.000	8.316	8.820	8.099	8.508	8.085	20.557	15.880

/Table 1 (Cont.)

TABLE 1 (Cont.)

Mean Specific Heats at Constant Pressure, Cp, between 300° and T°K.

In cal./mole. °K.

T°K	CO_2	H_2O	CO	H_2	N_2	O_2	OH	NO	HCl	CH_4	NH_3
3520	13.728	11.569	8.383	8.006	8.320	8.826	8.105	8.511	8.088		
3540	13.736	11.582	8.386	8.012	8.324	8.831	8.110	8.514	8.091		
3560	13.743	11.595	8.390	8.018	8.328	8.837	8.116	8.517	8.094		
3580	13.751	11.607	8.394	8.024	8.331	8.842	8.121	8.520	8.097		
3600	13.758	11.620	8.397	8.030	8.335	8.848	8.127	8.523	8.100		
3620	13.766	11.632	8.400	8.036	8.339	8.854	8.133	8.526	8.103		
3640	13.773	11.645	8.404	8.042	8.342	8.859	8.138	8.530	8.106		
3660	13.780	11.657	8.407	8.047	8.345	8.865	8.144	8.533	8.109		
3680	13.787	11.669	8.410	8.053	8.349	8.870	8.149	8.536	8.112		
3700	13.794	11.681	8.413	8.059	8.353	8.876	8.155	8.539	8.115		
3750	13.811	11.711	8.422	8.074	8.361	8.889	8.169	8.547	8.123		
3800	13.829	11.740	8.431	8.088	8.370	8.903	8.182	8.554	8.130		
3850	13.846	11.769	8.439	8.102	8.379	8.916	8.195	8.562	8.137		
3900	13.863	11.797	8.447	8.116	8.387	8.929	8.208	8.569	8.144		
4000	13.895	11.851	8.462	8.143	8.403	8.955	8.233	8.584	8.158	21.162	16.324
4500	14.040	12.097	8.529	8.272	8.477	9.071	8.359	8.655		21.654	16.688
5000	14.164	12.297	8.589	8.385	8.535	9.178	8.469	8.717		22.062	16.994

Explanation of Table 2 (Equilibrium Constants)

$$K_0 = \frac{p(CO).\ p(H_2O)}{p(CO_2).p(H_2)} \quad \text{or} \quad \frac{(CO).\ (H_2O)}{(CO_2).(H_2)}$$

$$K_1 = p(H)/\left\{ p(H_2) \right\}^{\frac{1}{2}}$$

$$K_2 = p(OH).\left\{ p(H_2) \right\}^{\frac{1}{2}} /p(H_2O)$$

$$K_3 = p(NO).\ p(H_2)/p(H_2O).\left\{ p(N_2) \right\}^{\frac{1}{2}}$$

$$K_4 = p(N)/\left\{ p(N_2) \right\}^{\frac{1}{2}}$$

$$K_5 = p(O).\ p(H_2)/p(H_2O)$$

$$K_6 = p(O_2).\left\{ p(H_2)/p(H_2O) \right\}^2$$

$$K_7 = p(CH_4).p(H_2O)/p(CO).\left\{ p(H_2) \right\}^3$$

$$K_8 = p(NH_3)/\left\{ p(N_2) \right\}^{\frac{1}{2}}.\left\{ p(H_2) \right\}^{3/2}$$

$$K_9 = \left\{ p(CO) \right\}^2 /p(CO_2) \text{ in presence of graphite.}$$

The gases are assumed 'perfect' in all cases.

/Table 2

TABLE 2

Equilibrium Constants (Low Temperature Region)

For Partial Pressures Expressed in Atmospheres

T^oK	Ko	K_7	K_8	K_9
500	0.00763			
600	0.03704		505.2×10^{-4}	
700	0.1113		111.4	
800	0.2486		34.91	0.01090
900	0.4566		13.97	0.1801
1000	0.7316	381.7×10^{-4}	6.640	1.900
1020	0.7513	224.0	5.816	2.843
1040	0.8237	134.2	5.118	4.192
1060	0.9003	91.94	4.527	6.091
1080	0.9806	50.97	4.023	8.728
1100	1.065	32.26	3.590	12.22
1120	1.136	20.76	3.216	16.97
1140	1.210	13.53	2.890	23.37
1160	1.286	8.954	2.607	31.81
1180	1.363	6.008	2.360	42.85
1200	1.443	4.089	2.144	57.15
1220	1.521	2.816	1.953	75.34
1240	1.601	1.963	1.784	98.42
1260	1.684	1.385	1.635	127.5
1280	1.767	98.72×10^{-6}	1.503	163.9
1300	1.852	71.09	1.385	208.9
1320	1.936	51.71	1.277	264.5
1340	2.019	37.96	1.182	331.8
1360	2.106	28.12	1.096	413.4
1380	2.193	21.02	1.020	511.8
1400	2.281	15.84	94.93×10^{-6}	629.8
1420	2.367	12.03	88.57	769.8
1440	2.454	9.204	82.79	936.1
1460	2.542	7.096	77.56	1132
1480	2.629	5.509	72.76	1361
1500	2.718	4.305	68.37	1629
1520	2.785		64.36	1937
1540	2.891		60.66	2295
1560	2.977		57.28	2706
1580	3.063		54.17	3178
1600	3.154		51.29	3717
1620	3.240		48.64	4326
1640	3.326		46.17	5016
1660	3.412		43.91	5795
1680	3.497		41.80	6674
1700	3.584		39.83	7656

/Table 2 (Cont.)

TABLE 2 (Cont.)

Equilibrium Constants (Low Temperature Region)

For Partial Pressures Expressed in Atmospheres

$T^oK.$	K_o	K_8	K_9
1720	3.670	38.01×10^{-6}	8750
1740	3.753	36.32	9968
1760	3.837	34.73	11320
1780	3.921	33.25	12820
1800	4.004	31.86	14480
1820	4.086	30.57	16290
1840	4.168	29.36	18290
1860	4.249	28.21	20490
1880	4.331	27.14	22890
1900	4.411	26.14	25510
1920	4.489	25.19	28340
1940	4.567	24.29	31420
1960	4.646	23.44	34770
1980	4.723	22.63	38380
2000	4.803	21.90	42290

/Table 2 (Cont)

TABLE 2 (Cont.)

Equilibrium Constants (High Temperature Region)

For Partial Pressures Expressed in Atmospheres

T^oK	Ko	K_1	K_2	K_3	K_4	K_5
1700	3.584	1.469×10^{-4}				
1720	3.670	1.769				
1740	3.753	2.121				
1760	3.837	2.532				
1780	3.921	3.013				
1800	4.004	3.570				
1820	4.086	4.215				
1840	4.168	4.960				
1860	4.249	5.816				
1880	4.331	6.795				
1900	4.411	7.914				
1920	4.489	9.191				
1940	4.567	10.64				
1960	4.646	12.28				
1980	4.723	14.14				
2000	4.803	16.22	1.629×10^{-4}			
2020	4.878	18.57	1.935			
2040	4.953	21.19	2.289			
2060	5.028	24.14	2.700			
2080	5.102	27.43	3.175			
2100	5.177	31.08	3.720			
2120	5.249	35.14	4.348			
2140	5.320	39.64	5.066			
2160	5.392	44.66	5.887			
2180	5.462	50.20	6.821			
2200	5.533	56.18	7.884			
2220	5.601	62.87	9.090			
2240	5.667	70.18	10.45			
2260	5.736	78.18	11.99			
2280	5.802	86.96	13.72			
2300	5.869	96.56	15.66			
2320	5.933	0.01070	17.83			
2340	5.998	0.01184	20.26			
2360	6.061	0.01307	22.98			
2380	6.127	0.01442	25.99			
2400	6.189	0.01587	29.36	1.759×10^{-4}		
2420	6.250	0.01745	33.10	2.027		
2440	6.311	0.01914	37.21	2.330		
2460	6.371	0.02098	41.79	2.673		
2480	6.431	0.02295	46.80	3.059		
2500	6.488	0.02508	52.37	3.494	0.7218×10^{-4}	0.9243×10^{-4}
2520	6.545	0.02736	58.46	3.983	0.8301	1.121
2540	6.603	0.02982	65.16	4.532	0.9528	1.358
2560	6.658	0.03245	72.51	5.145	1.091	1.638
2580	5.714	0.03526	80.58	5.830	1.247	1.970
2600	6.769	0.03829	89.35	6.594	1.422	2.360

/Table 2 (Cont)

TABLE 2 (Cont)

Equilibrium Constants (High Temperature Region)

For Partial Pressures Expressed in Atmospheres

T°K	Ko	K_1	K_2	K_3	K_4	K_5	K_6
				$\times 10^{-4}$	$\times 10^{-4}$	$\times 10^{-4}$	
2620	6.822	0.04152	0.00989	7.442	1.618	2.825	
2640	6.876	0.04495	0.01094	8.387	1.856	3.370	
2660	6.929	0.04863	0.01208	9.430	2.086	4.009	
2680	6.981	0.05254	0.01331	10.59	2.362	4.757	$\times 10^{-4}$
2700	7.033	0.05669	0.01465	11.83	2.669	5.627	2.129*
2720	7.082	0.06110	0.01610	13.26	3.009	6.643	2.512
2740	7.132	0.06583	0.01768	14.83	3.388	7.829	2.958
2760	7.181	0.07081	0.01937	16.54	3.807	9.196	3.472
2780	7.230	0.07608	0.02120	18.41	4.272	10.78	4.067
2800	7.279	0.08164	0.02318	20.46	4.785	12.61	4.754
2820	7.324	0.08748	0.02531	22.72	5.351	14.72	5.546
2840	7.370	0.09367	0.02761	25.19	5.977	17.15	6.454
2860	7.416	0.1002	0.03007	27.87	6.664	19.94	7.496
2880	7.463	0.1072	0.03271	30.81	7.422	23.13	8.688
2900	7.509	0.1148	0.03554	34.01	8.249	26.76	10.05
2920	7.553	0.1225	0.03858	37.49	9.156	30.91	11.60
2940	7.598	0.1306	0.04182	41.27	10.15	35.65	13.36
2960	7.638	0.1391	0.04529	45.38	11.24	41.02	15.36
2980	7.681	0.1481	0.04900	49.83	12.43	47.12	17.63
3000	7.723	0.1576	0.05297	54.66	13.72	54.01	20.19
3020	7.762	0.1674	0.05718	59.84	15.12	0.006179	23.09
3040	7.803	0.1778	0.06166	65.46	16.65	0.007060	26.47
3060	7.843	0.1888	0.06643	71.55	18.50	0.008050	30.05
3080	7.881	0.2002	0.07153	78.09	20.10	0.009164	34.19
3100	7.923	0.2121	0.07695	85.19	22.07	0.01042	38.86
3120	7.958	0.2247	0.08268	0.009279	24.18	0.01182	44.06
3140	7.997	0.2328	0.08874	0.01009	26.48	0.01340	49.87
3160	8.034	0.2513	0.09515	0.01096	28.94	0.01515	56.37
3180	8.072	0.2656	0.1020	0.01191	31.61	0.01710	63.63
3200	8.112	0.2805	0.1091	0.01291	34.49	0.01929	71.76
3220	8.147	0.2959	0.1168	0.01399	37.58	0.02171	0.008073
3240	8.183	0.3121	0.1248	0.01515	40.93	0.02442	0.009074
3260	8.219	0.3289	0.1332	0.01637	44.50	0.02740	0.01018
3280	8.254	0.3463	0.1419	0.01768	48.35	0.03072	0.01141
3300	8.292	0.3747	0.1516	0.01908	52.48	0.03439	0.01277
3320	8.324	0.3836	0.1615	0.02058	56.92	0.03846	0.01427
3340	8.358	0.4032	0.1720	0.02217	61.65	0.04292	0.01502
3360	8.390	0.4236	0.1829	0.02386	66.71	0.04786	0.01774
3380	8.424	0.4447	0.1944	0.02565	72.13	0.05330	0.01975
3400	8.457	0.4670	0.2064	0.02756	77.91	0.05928	0.02197

* The value in Pike's table is incorrect.

/Table 2 (Cont)

TABLE 2 (Cont)

Equilibrium Constants (High Temperature Region)

For Partial Pressures Expressed in Atmospheres

T^oK	Ko	K_1	K_2	K_3	K_4	K_5	K_6
3420	8.489	0.4898	0.2191	0.02959	0.008409	0.06586	0.02440
3440	8.519	0.5134	0.2324	0.03174	0.009067	0.07307	0.02705
3460	8.549	0.5379	0.2462	0.03402	0.009770	0.08095	0.02997
3480	8.578	0.5631	0.2608	0.03642	0.01052	0.08960	0.03316
3500	8.608	0.5896	0.2762	0.03899	0.01131	0.09917	0.03667
3520	8.638	0.6166	0.2920	0.04169	0.01216	0.1094	0.04048
3540	8.666	0.6445	0.3087	0.04454	0.01305	0.1208	0.04464
3560	8.692	0.6736	0.3261	0.04756	0.01401	0.1331	0.04919
3580	8.720	0.7037	0.3445	0.05076	0.01502	0.1467	0.05416
3600	8.744	0.7350	0.3636	0.05413	0.01609	0.1612	0.05953
3620	8.770	0.7670	0.3835	0.05768	0.01723	0.1772	0.06539
3640	8.798	0.7998	0.4041	0.06138	0.01843	0.1944	0.07171
3660	8.822	0.8341	0.4259	0.06534	0.01970m	0.2131	0.07863
3680	8.847	0.8692	0.4483	0.06945	0.02104	0.2334	0.08606
3700	8.872	0.9057	0.4719	0.07379	0.02246	0.2555	0.09414
3750	8.937	1.000	0.5346	0.08563	0.02635	0.3184	0.1173
3800	8.994	1.104	0.6040	0.09993	0.03082	0.3951	0.1453
3850	9.053	1.213	0.6801	0.1140	0.03588	0.4871	0.1791
3900	9.107	1.332	0.7635	0.1306	0.04162	0.5975	0.2193
4000	9.208	1.592	0.9535	0.1700	0.05537	0.8859	0.3245
4500	9.632	3.458	2.434	0.5320	0.1914	4.859	1.764
5000	9.902	6.448	5.381	1.326	0.5188	19.08	6.882

/Table 3

TABLE 3

Values of G' for Given Values of $\overline{Cp}$

$\overline{Cp}$	0	1	2	3	4	5	6	7	8	9
7.6	1.599	1.599	1.599	1.600	1.600	1.601	1.602	1.602	1.602	1.603
7.7	603	604	604	605	605	606	606	607	607	607
7.8	608	608	609	609	610	610	611	611	612	612
7.9	612	613	613	614	614	615	615	616	616	617
8.0	617	617	618	618	619	619	620	620	621	621
8.1	621	622	622	623	623	623	624	624	625	625
8.2	626	626	626	627	627	628	628	629	629	629
8.3	630	630	631	631	631	632	632	633	633	633
8.4	634	634	635	635	635	636	636	637	637	637
8.5	638	638	639	639	639	640	640	641	641	641
8.6	642	642	643	643	643	644	644	645	645	645
8.7	646	646	647	647	647	648	648	648	649	649
8.8	649	650	650	651	651	651	652	652	653	653
8.9	653	654	654	655	655	656	656	656	656	657
9.0	657	657	658	658	658	659	659	659	660	660
9.1	660	661	661	662	662	662	663	663	663	664
9.2	664	664	665	665	665	666	666	666	667	667
9.3	667	668	668	669	669	669	670	670	670	670
9.4	671	671	671	672	672	673	673	673	675	674
9.5	674	675	675	675	676	676	676	677	677	677
9.6	678	678	678	678	679	679	679	680	680	681
9.7	681	681	682	682	682	682	683	683	683	683
9.8	684	684	685	685	685	686	686	686	686	687
9.9	687	687	688	688	688	689	689	689	690	690
10.0	690	691	691	691	691	692	692	692	693	693
10.1	693	694	694	694	695	695	695	695	696	696
10.2	696	697	697	697	697	698	698	698	699	699
10.3	699	700	700	700	700	701	701	701	702	702
10.4	702	702	703	703	703	704	704	704	705	705
10.5	705	705	706	706	706	707	707	707	707	708
10.6	708	708	708	708	709	709	709	709	710	710
10.7	710	711	711	711	711	712	712	712	712	713
10.8	713	713	713	714	714	714	715	715	715	716
10.9	716	716	716	717	717	717	717	718	718	718
11.0	719	719	719	719	719	720	720	720	720	721
11.1	721	721	721	722	722	722	723	723	723	723

/The

The Calculation of Specific Impulse

Calculate according to the procedure described in A.R.E. Report No. 25/49, the combustion temperature, Tc, the number of moles of resultant gas per 100 kg, n, and the specific heat/mole for the resultant gases, Cp.

Look up, in Table 3, the value of G' corresponding to the value of Cp.

Find the product, $n \times Tc$, of the number of moles in 100 kg. of resultant gases, and the calculated combustion temperature.

Place a straight edge across these values on the two outer scales of the nomograph on the next page. The intersection of the edge with the centre scale gives the value of the specific impulse.

S.No.359.
M.No.16/54.BM

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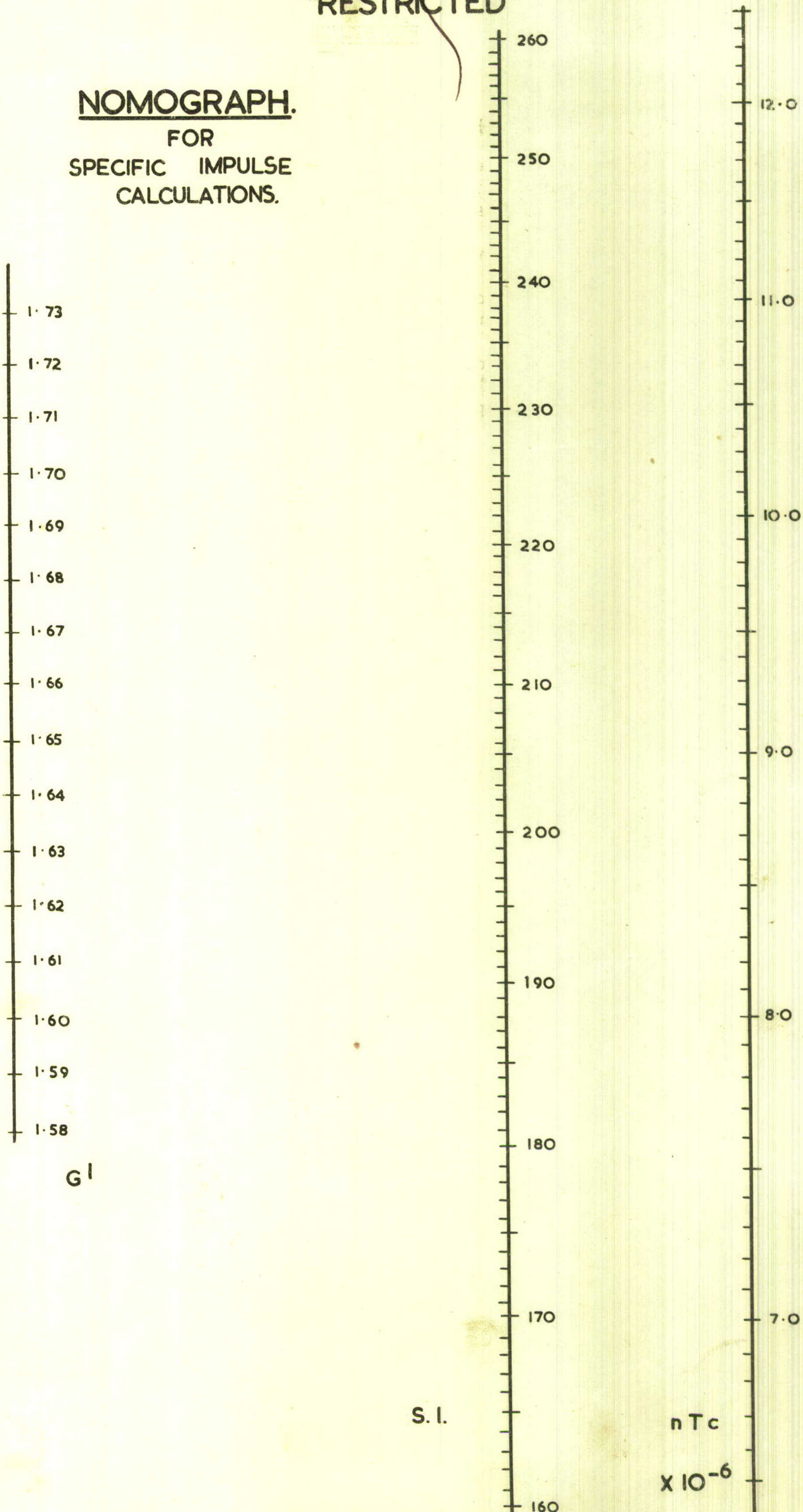
NOMOGRAPH.
FOR
SPECIFIC IMPULSE
CALCULATIONS.



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E.R.D.E. Technical Memorandum No. 4/M/54

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J.H.C. Vernon August, 1954.

A number of tables and a nomograph for calculating the combustion temperature and specific impulse of propellants are presented. The tables are extensions and modification of those already given by Pike. It is claimed that their use, in conjunction with the nomograph, considerably reduces the labour of calculating specific impulse.

14 pp., 1 fig. 3 tables.

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J.H.C. Vernon — August, 1954.

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14 pp., 1 fig., 3 tables.

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